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# How to stay afloat in the lacrimal pool

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Thomason, Tom Ski and McBride, Charles Albert, "How to stay afloat in the lacrimal pool" (1995). *College of Optometry*. 1148.

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## How to stay afloat in the lacrimal pool

### Abstract

Compensating for a diagnostic RGP contact lens fit flatter or more steeply than the cornea when ordering a prescription has been a concern of optometrists since the invention of rigid contact lenses.

Traditionally, the convention of considering the lacrimal lens induced power has been a means of attaining the compensating power when a lens is ordered. The convention is SAMFAP, steep add minus, flat add plus. When a lens is fitted steeply, minus must be added to the ordered lens, and the converse for a flat lens. While this has usually resulted in a satisfactory lens for the patient, the reason for the convention is incorrect and has created a misunderstanding for those prescribing. The lacrimal lens induced by a steeply fit contact lens is not a plus lens as understood by most students but is really a minus lens. While the lacrimal lens is a useful memory device, it should not be used as an explanation for adding minus power to a steeply fit rigid contact lens. Furthermore, the convention overestimates the amount of minus to be ordered by 0.31 D for every diopter that it is fitted steep.

### Degree Type

Thesis

### Degree Name

Master of Science in Vision Science

### Committee Chair

Jurgen R. Meyer-Arendt

### Subject Categories

Optometry

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# HOW TO STAY AFLOAT IN THE LACRIMAL POOL

By

TOM SKI THOMASON  
CHARLES ALBERT MCBRIDE

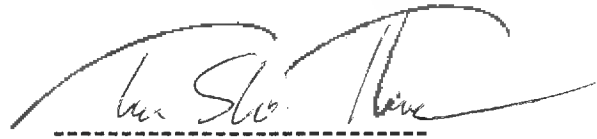
A thesis submitted to the faculty of the  
College of Optometry  
Pacific University  
Forest Grove, Oregon  
for the degree of  
Doctor of Optometry  
May, 1995

Adviser:

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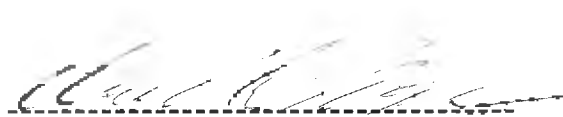
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CHARLES ALBERT MCBRIDE



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Tom Ski Thomason, born in Fontana, California in February of 1970, attended Pacific University and received the degree of Bachelor of Science. Presently he is a third year optometry student and plans on continuing his professional student lifestyle by enrolling in medical school in the fall of 1995. During his 8th grade year, Tom received the award of Optimist of the Month in wood working for the Bend-Lapine school district. In addition, upon his graduation from Bend Senior High School, he was voted as having the "best legs" for the class of 1988. More recently, during his second year of optometry school, Tom received the "Corneal Divot" award after gauging out Charlie's cornea while performing contact tonometry.

Charles Albert McBride, born in Portland, Oregon in August of 1969 attended Oregon State University for three years before transferring to Pacific University and receiving the degree of Bachelor of Science. Presently he is a third year optometry student and will be attending medical school to further his optometric education. In addition to performing the "Nutcracker Sweet" in the 4th grade, he received the Whitford Junior High School typing award. Later in High School, Charles was suspended for punching a hole in the wall. More recently, upon purchasing his daily ration of Copenhagen® from the local "Pic-A-Deli" store, he won \$1 after correctly scratching his Oregon Lottery ticket.

## ABSTRACT

Compensating for a diagnostic RGP contact lens fit flatter or more steeply than the cornea when ordering a prescription has been a concern of optometrists since the invention of rigid contact lenses. Traditionally, the convention of considering the lacrimal lens induced power has been a means of attaining the compensating power when a lens is ordered. The convention is SAMFAP, steep add minus, flat add plus. When a lens is fitted steeply, minus must be added to the ordered lens, and the converse for a flat lens. While this has usually resulted in a satisfactory lens for the patient, the reason for the convention is incorrect and has created a misunderstanding for those prescribing. The lacrimal lens induced by a steeply fit contact lens is not a plus lens as understood by most students but is really a minus lens. While the lacrimal lens is a useful memory device, it should not be used as an explanation for adding minus power to a steeply fit rigid contact lens. Furthermore, the convention overestimates the amount of minus to be ordered by 0.31D for every diopter that it is fitted steep.

### AWKNOWLEGEMENTS

The authors would like to express their special thanks to Dr. Jurgen Meyer-Arendt for his clairvoyant insight and always helpful comments. Thanks also to the faculty of Pacific University College of Optometry.



The concept of tear lenses has been documented since the development of contact lenses. When a rigid contact lens is fitted more or less steeply than the cornea, the tears pool and form another lens. The pioneers of contact lenses accounted for this change in power and named this pool of tears the fluid lens. Other names used for it are the "lacrimal lens" or "tear lens."

Compensating for the power induced by the tear lens, has always been a concern of Optometrists. It has become so embedded in our thinking of RGP fitting that many of us do not separate the convention from the truth. This paper will outline the convention and the reason for it, and why it is accepted so thoroughly. The primary focus of the paper is the reason that it is merely a convention and why it may not be as valid as previously thought.

It is a fact that extra minus power must be added to a contact lens that has been fitted more steeply than the corneal surface. This is challenged by no one. The purpose of the convention is to help students and clinicians remember the above relationship, keeping in mind that the converse is true if a rigid lens is fitted flatter than the cornea. The convention is: "Steep add minus, flat add plus," or "SAMFAP." In order to ensure that students don't forget it, they are reminded to consider the shape of the tear lens when, for instance, the rigid lens is fitted steeply. This memory device is fine in that it works fairly well clinically, but it has come to be considered by many as more than simply a convention. For instance, Mandell states: "If the contact lens is fitted steeper than K, it will be found that the tear fluid lens formed between the contact lens and the cornea contributes additional plus power to the power of the contact lens when it is worn on the eye."<sup>1</sup> Earlier than Mandell, Obrig, in 1947, stated that, "Plus liquid lenses become more plus with added thickness, and minus liquid lenses become less minus."<sup>2</sup> Lowther explains the optics in a little more detail for a lens fitted steeply on a one diopter myope.

The lens would be 1.00D steeper than the cornea (47.00 vs. 46.00 D). The lacrimal lens will have a +1.00 D power; therefore, to fit this patient properly, the contact lens must have a -2.00 D power, -1.00 to compensate for the +1.00 D lacrimal lens plus another -1.00 for the patient's myopia.<sup>3</sup>

The above statement by Mandell and those like it are misleading. These statements are typical of contact lens fitters and professors, but the statements have become an explanation for the convention, when in reality the convention is only a memory device. The convention of a plus tear lens requiring a minus power compensation, works clinically, but is based on the untrue assumption that a convex tear lens is of plus power. Therefore, it cannot be used as the real explanation for adding the required compensating minus power.

The reason contact lens fitters have started believing in the convention as an explanation seems understandable. Just look at the shape of the tears in figure 1 below.

Fig. 1

#### A PLUS TEAR LENS?

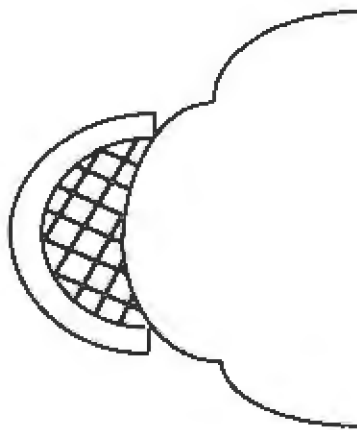
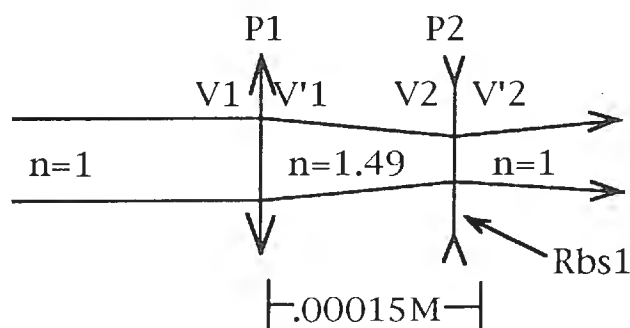


Fig. 2

Given:

1. Index of refraction (n) of contact lens = 1.49
2. n of tears = 1.336
3. Radius of curvature of cornea( $R_c$ ) = 7.8mm
4. Curvature of contact lens =  $R_{bs1}$
5. Thickness(t) of contact lens = 0.15mm
6. Lens to correct at corneal plane = -5.00D

Fig. 3



$$V_2' = -5.00D$$

$$P_2 = (n' - n) / R_{bs1} = (1.00 - 1.49) / 0.0078m = -62.82D$$

$$V_2 = V_2' - P_2 = (-5.00D) - (-62.82) = 57.82D$$

$$V_1' = [(1/V_2) + t]^{-1} = [(1/57.82D) + 0.00015m]^{-1} = 57.32D$$

$$P_1 = V_1' - V_1 = 57.32 - 0.00D = 57.32D$$

Anyone can see that the space filled in with tears takes the form of a plus lens. But is it really a plus lens? When examined with simple optics, as done below, this seemingly plus powered lens is shown to deliver extra minus power to the system. Therefore, there must be a different reason for adding minus to a diagnostic lens when fitting the lens steeper than the corneal curve. This will be addressed shortly, but first it must be accepted that the seemingly plus tear lens actually contributes extra minus power to the system.

Just because a surface is convex, it does not necessarily contribute plus power; indices of refraction must also be taken into account. Refraction only occurs at surfaces, so a simple examination of the equation for refraction at a surface,  $F = (n' - n) / r$ , (equation #1), shows that the boundary between the contact lens media and the tear fluid is really a minus surface. The index of refraction,  $(n)$ , is 1.49 for PMMA lenses, and the index of the tears,  $(n)$ , is approximately 1.336. The radius of curvature,  $(r)$ , is by convention a positive value for convex surfaces. Given these conditions, one can see that  $(n'-n) / r$  is a minus value and that as  $(r)$ , becomes smaller, yielding a steeper curve, the minus value becomes increasingly minus.

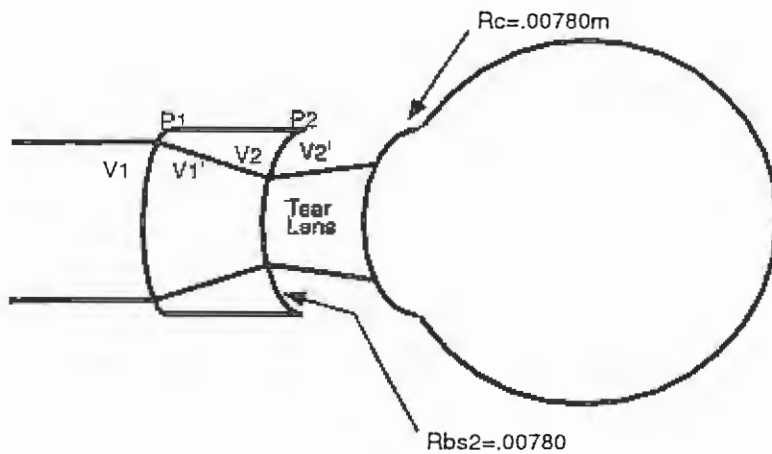
Because it is crucial to accept this step before going on to the next, we present an example: Suppose, for instance, that we begin with a patient needing -5.00 diopters at the corneal plane to correct their myopia. If we start with a given number of constants as shown in figure 2, we can calculate the parameters for the lens needed to correct the myopia. We can then run light through two different systems and compare vergences exiting the contact lens. The difference in the parameters of the two systems will be the steepness of fit. The first calculation will be run through a lens fit "on K," and the second through a lens fit steeper by some arbitrary amount. The difference between the two exit vergences will be equal to the contribution of the lacrimal lens.

Following figure 3, the back vertex power, ( $V_2'$ ), of the contact lens to correct the myopia needs to be  $-5.00D$ . The back surface radius of curvature, ( $R_{bs1}$ ), is first going to be made the same as the cornea,  $7.80mm$ . In air, the back surface power, ( $P_2$ ), found by equation #1 is  $-62.82D$ . Working backwards through the lens system, the vergence entering the back surface of the lens is obtained by subtracting ( $P_2$ ) from ( $V_2'$ ). To get the vergence leaving the front surface of the lens, ( $V_1'$ ), the thickness of the lens must be taken into account. This is so because, by definition, a thick lens is one such that the thickness is greater than 1% of the radius of curvature. As shown in line 4 in figure 3, ( $V_1'$ ) =  $57.32D$ . The power of the front surface in air is ( $V_1'$ )-( $V_1$ ) =  $57.32D$ . All these previous calculations were used simply to attain the parameters of the contact lens to be used in our two vergence systems: one with the contact lens fitted "on K," and the other with the lens fit steeply.

What we end up with is a lens  $0.15mm$  thick with a front surface power of  $57.32D$  and a back surface power of  $-62.82D$ . Using this lens on an eye, we run light through the system shown in figure 4. Coming essentially from infinity, the vergence entering the contact lens, ( $V_1$ ), is zero. The vergence leaving the front lens surface, ( $V_1'$ ), is the addition of the entrance vergence, ( $V_1$ ), and the power of the front lens surface, ( $P_1$ ), which equals  $57.32D$ . Taking into consideration the thickness of the lens, the vergence entering the back lens surface, ( $V_2$ ), is  $57.82D$ . To get the vergence exiting the contact lens, ( $V_2'$ ), the entrance vergence, ( $V_2$ ), is added to the power of the back lens surface, ( $P_2$ ). The power of the back lens surface, however, has changed because the contact lens is now resting against a layer of tears as opposed to air. Using equation #1 again, the power of the back surface, ( $P_2$ ), is  $-19.74D$ .  $V_2'$  is then  $38.08D$ .

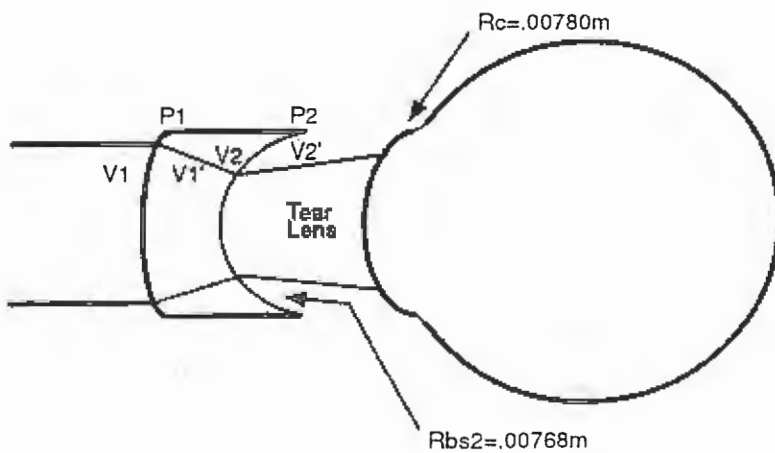
The second system is approached in the same manner, with all the same contact lens parameters but with a steeper back curve, ( $R_{bs2}$ ). Steepness of

Fig. 4



- (1)  $V1 = 0.00D$
- (2)  $P1 = 57.32D$
- (3)  $V1' = 57.32D$
- (4)  $V2 = 57.82D$
- (5)  $P2 = (n' - n) / Rbs2 = (1.336 - 1.490) / 0.0078m = -19.74$
- (6)  $V2' = V2 + P2 = (57.82D) + (-19.74D) = 38.08D$

Fig. 5



- (1)  $V1 = 0.00D$
- (2)  $P1 = 57.32D$
- (3)  $V1' = 57.32D$
- (4)  $V2 = 57.82D$
- (5)  $P2 = (n' - n) / Rbs3 = (1.336 - 1.490) / 0.00768m = -20.05$
- (6)  $V2' = V2 + P2 = (57.82D) + (-20.05D) = 37.77D$

curvature in optometry is traditionally given in diopters, but because curvature in these units changes depending upon the media the surface is in, we will primarily give the curvature in units of millimeters, supplemented with dioptric units. In this second system, the back curve will be altered from 7.80mm to 7.68mm, which is the same as making the back curve 1.00D steeper, from -62.82D to -63.82D.

As shown in figure 5, the vergences are identical until the light enters the back lens surface. The vergence exiting this second system is once again the vergence entering the back surface, (V2), added to the power of the back surface, (P2). With the change in curvature, we expect a change in power predicted again by equation #3 equaling 20.05D. Adding (V2) to (P2), the vergence exiting the second system is 37.77D.

Because the tear lens thickness is less than 1% of its radius of curvature, it can be considered a thin lens and additional power usually attributed to thickness is neglected. We can then compare the exit vergences of the two systems to attain the power contributed by the lacrimal lens. We can stop here because the tear lens is considered thin, and because the indices of refraction between the tears and cornea are almost identical, 1.336 and 1.3375 respectively. Recall that the vergences exiting the two lens systems were 38.08D and 37.77D, respectively, the difference between them being 0.31D. In other words, the vergence exiting the second system where the lens was fit steeply is 0.31D less than the first system. For a lens made steeper by 0.12mm or 1.00D in air, the lacrimal lens contributes -0.31D. The lacrimal lens is minus.

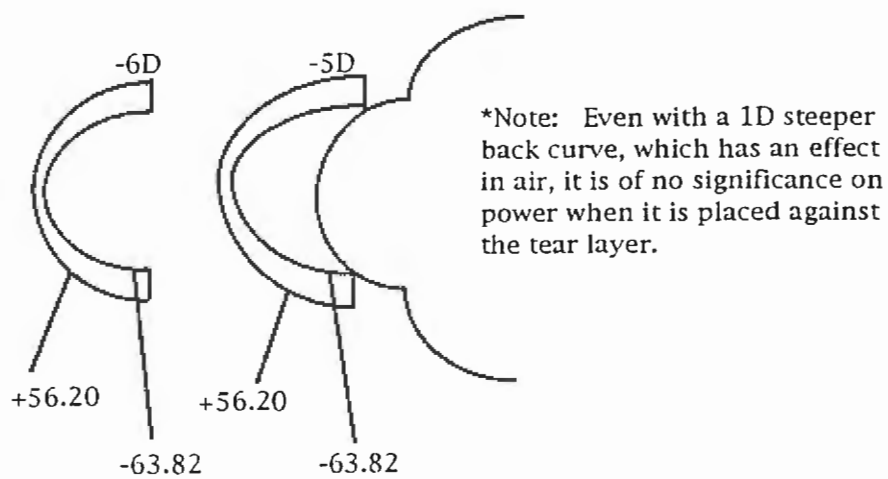
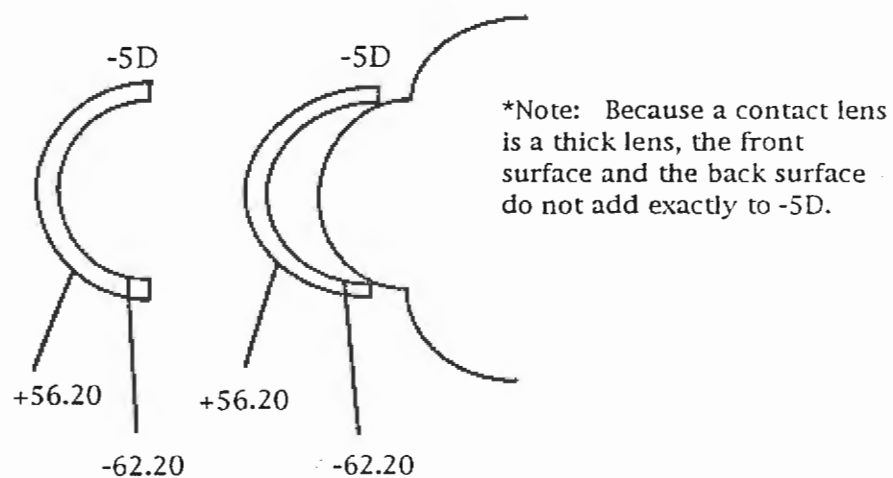
Given that a convex lacrimal lens is one of minus power, the next issue must be raised. The problem is that a part of the convention is being used to explain the reason for the convention. Remember previously that it was stated that extra minus power must be added to a patient's contact lens prescription

when a lens must be fit more steeply than the corneal surface. Also, recall that many clinicians justify this by remembering the shape of the subsequent tear lens; "the tear lens is convex, adding plus power to the system, so minus power must be added to account for this." But it has just been shown definitively that the convex tear lens contributes additional minus power to the system.

The reason that minus power must be added to a steeply fit contact lens has nothing to do with the lacrimal lens. The only way to make the back curve or base curve of a lens steeper without changing the functional correcting power of the original lens **on the eye** (not in air) is to add minus, which has nothing to do with the lacrimal lens' power addition. Consider the same myope discussed earlier, in figure 3, this time shown in figure 6. The subject was perfectly corrected with the contact lens in figure 3, a -5.00D lens. Assume, for instance, that the lens was riding a bit low. To keep the lens from sliding, the lens can be made steeper, just as was done in figure 3. Of course, the myopia must be perfectly corrected as before, so, in order to keep the correction the same, the front curve must not be changed. If it were to be changed, the power of the lens on the eye would be altered because the majority of the refraction occurs at the front surface, a result of the large differences in indices of refraction. However, making the lens 0.12mm or 1.00D steeper on the back curve makes essentially no power difference because the change is at a junction where the indices are nearly the same, the tears and cornea. If one looks at the lens with the new steeper back curve in air, through a lensometer, the power of the lens shows -6.00D. Again, even though the lens is now a -6.00D lens, the functional power of the lens on the eye is still -5.00D. On the other hand, ordering the same power of -5.00D, would require altering the front curve by the same amount as the back curve, which would definitely change the functional power of the lens on the eye. To keep the front curve the same and to



Fig. 6



make the base curve steeper, minus must be added to the prescription, hence, "Steep Add Minus."

In the progression, it would be natural to ask where the new calculations of the tear lens come in. They should not be ignored. It is a fact that a lens fitted steeply on the cornea induces more minus in the tears, so this must be accounted for. Recall that for a lens fitted 1.00D steep, the lacrimal lens contributed -0.31D. For a lens fitted 1.00 steep, we need to add -1.00D to maintain the functional power of the lens. But since the tear lens is already contributing -0.31D, one only needs to add -0.69D. So, the idea of "steep add minus" still applies, just not as much minus. This same process works in reverse for lenses fitted flatter than the corneal surface.

This also suggests why, clinically, those prescribing contacts have been able to ignore the effects of the tear lens. A lens needs to be fitted significantly steeply before the tears induce any significant power. Again, a lens fitted a whole diopter steep induces only -0.31D. Lenses are not usually fit steeply enough to produce a tear power large enough to make a significant difference clinically.

A question that must be asked is why have so many contact lens fitters assumed that a steeply fit contact lenses produces a plus tear lens? Nearly all researchers who addressed these calculations in the past assumed that the contact lens/ tear lens/ eye systems are separated by an infinitely thin film of air. For example, in Contact Lens Theory and Practice, the contact lens-fluid lens system is treated "as a three-surface system, with the contact lens and the fluid lens separated by an infinitely thin layer of air."<sup>4</sup> Researchers do this, they say, to simplify the calculations. Whether or not it makes the calculations easier, the existence of air is an untrue assumption. There is no air between the contact lens and cornea. Using the air film does create the plus tear lens which is

always mentioned when a lens is fitted steeply, but, again, the fallacy is in performing the calculations in air. There is no air, and, as a result, the tear lens becomes increasingly more minus as the lens is fitted more steeply.

During the course of research for this paper it became apparent that there is a wide gap of misunderstanding of the tear lens compensation, especially in optometry students and new practitioners. Even though the initial contact lens researchers address the calculations as stated, it is inconceivable that they do not understand the true reason for adding minus to a steeply fit contact lens. Occasionally, the authors came across more experienced practitioners who seemed to understand the problem. In one recent publication, it is stated emphatically that the "lacrimal lens theory is a clever mental device that has been invented to explain certain optical effects of lens/cornea fitting relationships."<sup>5</sup> It also states that the tear interface is always a minus surface. In the same publication, however, undermining the understanding that the lacrimal lens theory is a memory device, a different author reverts back to the statement: "If the lens is fitted steeper than K, a plus tear lens power is created."<sup>6</sup> Even within the same publication there is contradiction.

In conclusion, it is evident that the true reason for the convention is understood by some, primarily the pioneering researchers and a few practitioners. The desired achievement of this paper is to bridge the gap between those who truly understand this issue, and those who have adopted the convention as the truth. This paper, however, will not greatly change the clinical world of contact lenses. In fact, it will not make much of a difference to anyone prescribing. The only area in which it might improve fitting is when RGP's are fitted very steeply or on highly toric corneas, where taking the true effect of the tear lens into account would result in an improved fit. An area where it will offer improvement is in how the theory of fitting RGP's is taught to

students. One might argue that the old lacrimal lens theory is just a convention to help students remember the need to "Steep Add Minus," but it would be much more beneficial to understand the truth about contact lens fitting. It would improve the way students fundamentally think about fitting. It would help them understand more complex problems and ultimately facilitate right thinking as clinicians and in new aspects of research.

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